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PROGRESS REPORT NO. 8

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INTRODUCTION

This is the eighth progress report on research and development task 4. This month's report covers additional work done on a pulse duration modulated communication system.

The P. D. M. modulator was re-designed with a view toward improving the pulse deviation, duty cycle efficiency and index of modulation.

The P. D. M. demodulator was re-designed to improve its filtering action.

The new units were tested on a closed wire basis, and the results are summarized.

DESIGN OF EQUIPMENT

On the basis of the design of the equipment for the three pulse systems, it was decided that P. D. M. showed the most promise. On that premise it was further decided that the P. D. M. modulator design could be improved.

The original design had a number of disadvantages. The maximum pulse deviation was limited to 1.4 microseconds, which in turn restricted the dynamic range and the maximum index of modulation. The minimum usable pulse width had to be maintained wide because the maximum deviation varied directly with pulse width. This was undesireable because the duty cycle required a narrow pulse for efficiency.

The following is a description of the equipment designed to secure these advantages. The pulse duration modulator is indicated in Figure 1. The first stage is the original blocking oscillator that provides a jitter-free trigger pulse of 8 kilocycles. This triggers a saw tooth wherein the beginning of the cycle is a fast rise time of the order of 0.4 microseconds. The decay slope is reasonably linear and relatively slow, on the order of 12 microseconds.

The saw tooth generator is designed to provide the desired wave shape on the discharge half of the blocking oscillator signal. This, in turn, resulted in a positive going saw tooth at the generator output. The rectifiers eliminate the negative portion which corresponds to the positive leading edge of the blocking oscillator signal.

A bias control on the grid of the input section of the multivibrator maintains the input half of the tube at cut-off. By means of this bias setting, the additional voltage required from the saw tooth wave shape is determined. The instant of triggering the multivibrator is independent of the bias setting due to the fast rise time of the saw tooth. However the instant at which the decay slope will reduce below the trigger point is controlled by the bias setting. In this way the portion of the saw tooth to be used is controlled.

The linearity of the saw tooth decay determines the linearity of deviation. This in turn is one of the factors that determines the fidelity of the system. The resistor-capacitor values in the plate circuit of the saw tooth generator determine the time of decay of the saw tooth. This is related to the slope of the decay which in turn determines the maximum deviation.

The modulating audio signal is superimposed on the saw tooth wave form as it triggers the multivibrator. The instant of triggering is independent of the audio signal, due to the fast rise time of the saw tooth. However the instant at which the decay slope reaches the cut-off point of the multivibrator is readily modified by the modulating audio voltage.

A saw tooth generator was designed using a thyratron as the generator stage. It was found that these gas tubes were noisy and had poor interchangeability qualities. They were discarded in favor of a vacuum tube. The final design utilized the second half of a twin triode that was available for the blocking oscillator.

The demodulator was redesigned to eliminate tuned rejection filters. This was found to be necessary because the pulse frequency varied when the blocking oscillator tube was changed.

By the use of low pass filters for the elimination of the pulse repetition frequency, this effect was made negligible.

TESTING

The following tests were made on the individual sections of the equipment. The two cascaded audio amplifiers were designed for a frequency response with the 6 decibel attenuation points at 90 and 400,000 cycles per second.

Figure 3 is a plot of modulating audio frequency versus deviation of pulse duration. This indicates that the modulator is not subject to frequency distortion.

Figure 4 is a plot of deviation of pulse duration versus amplitude of modulating audio voltage, Figure 5 is a plot of deviation versus audio voltage output at the demodulator. This test can be readily followed on the closed wire diagram, Figure 2. With maximum audio modulation, the resulting maximum deviation was 9 microseconds, however the curve is linear to 8 microseconds.

Figure 6 is a plot of the overall frequency response of the unit on a closed wire test. It indicates the 6 decibel attenuation points as 190 and 3000 cycles per second.

A test for an output signal to noise of 2 to 1 was found to correspond to a deviation of 60 millimicroseconds. The maximum linear deviation of 8 microseconds resulted in a signal to noise of 150:1.

Various oscillograms were taken, and the tests points are indicated on Figure 2 as follows:

Figure 7: The plate of the blocking oscillator indicates the pulse repetition interval as 130 microseconds or a pulse frequency of 7700 cycles per second.

Figure 8: The input of the saw tooth generator indicates that the tube is being driven positive during the positive portion of the pulse.

Figure 9: The output of the saw tooth generator is shown as a saturated signal on the negative portion and a positive saw tooth that corresponds to the discharge cycle of the stage.

Figure 10: This is the saw tooth wave form as it is used to modulate the multivibrator. The rise time is 0.4 microseconds. The decay time is 8 microseconds.

Figure 11: The audio input is shown as a 1000 cycle per second modulating signal.

Figure 12: The plate of the third audio amplifier indicates an audio gain of 48 db. The saw tooth is superimposed on the audio.

Figure 13: The plate of the output section of the multivibrator indicates a P.D.M. pulse. The pulse width is 7.5 microseconds.

Figure 14: The input to the demodulator section indicates that the multivibrator output has been divided down 80 times. This is the order of pulse amplitude normally derived from the noise clipper section of the receiver.

Figure 15: The plate of the pulse amplifier indicates the stage gain as 18 decibels. The square wave pulse has been converted to a saw tooth by the inductive loading of the low pass filter.

Figure 16: The input to the second stage indicates the effectiveness of the low pass filter.

Figure 17: The plate of the first audio amplifier indicates a stage gain of 28 decibels The ripple amplitude corresponding to the pulse repetition frequ.ncy remains unchanged.

Figure 18: The output of the second low pass filter demonstrates the effectiveness of the filter. The ripple is negligible and on the order of noise level.

Figure 19: The output of the output transformer was measured across a resistive load. The curve is reasonably smooth indicating the fidelity of the overall closed wire system. The power gain of the stage is 35 decibels.

CONCLUSIONS AND FUTURE PLANS

The pulse duration modulator was redesigned to accomplish the following advantages over the previous design:

1 -- Independent of normal variation of tube parameters when tubes are replaced.

2 --Maximum pulse width deviation of 9 microseconds as contrasted with a previous figure of 1.4 microseconds.

3 --The pulse width can be adjusted independent of deviation.

4 --The duty cycle lowered for greater efficiency from 0.092 to 0.053.

5 --The maximum permissible index of modulation raised from 5.4% to 67%.

The pulse duration demodulator was redesigned to make its pulse filtering action independent of normal pulse frequency variations due to tube replacements.

It is planned to complete the RF sections of the transmitter and receiver and test the pulse duration modulation unit on a system basis via a radio link.

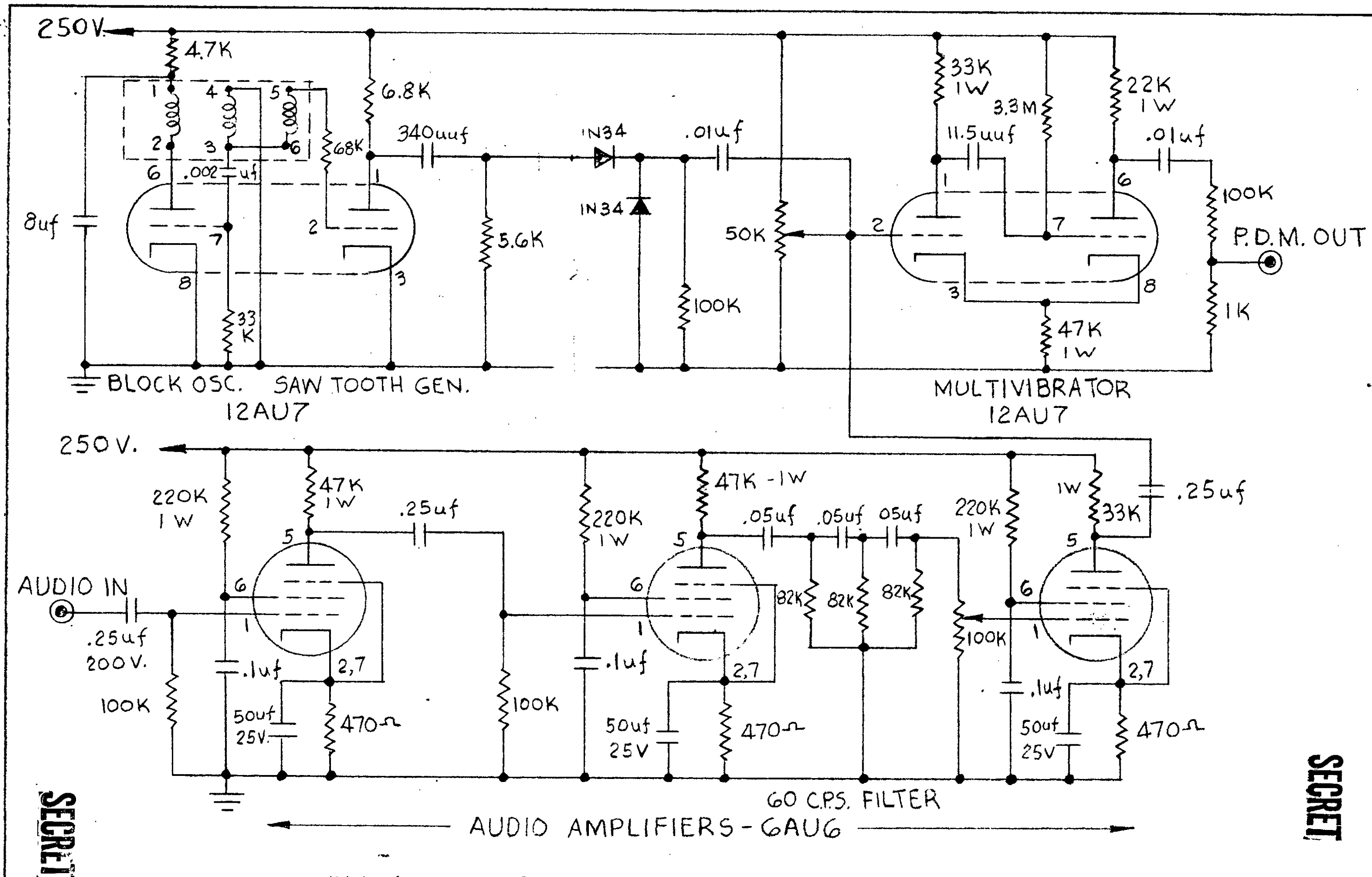

FIG. 1 PULSE DURATION MODULATOR

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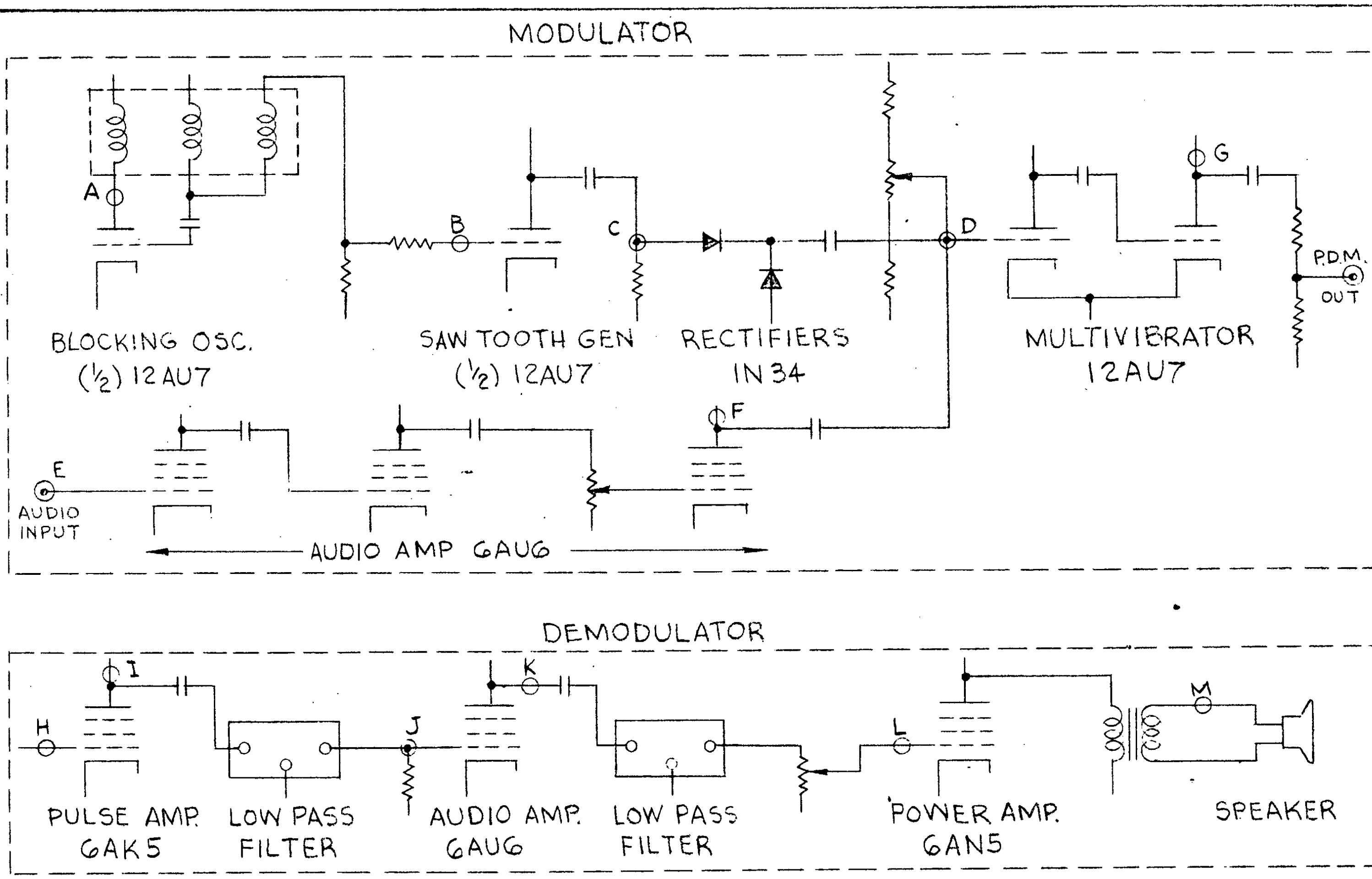

FIG. 2 OUTLINE OF P.D.M. MODULATOR & DEMODULATOR

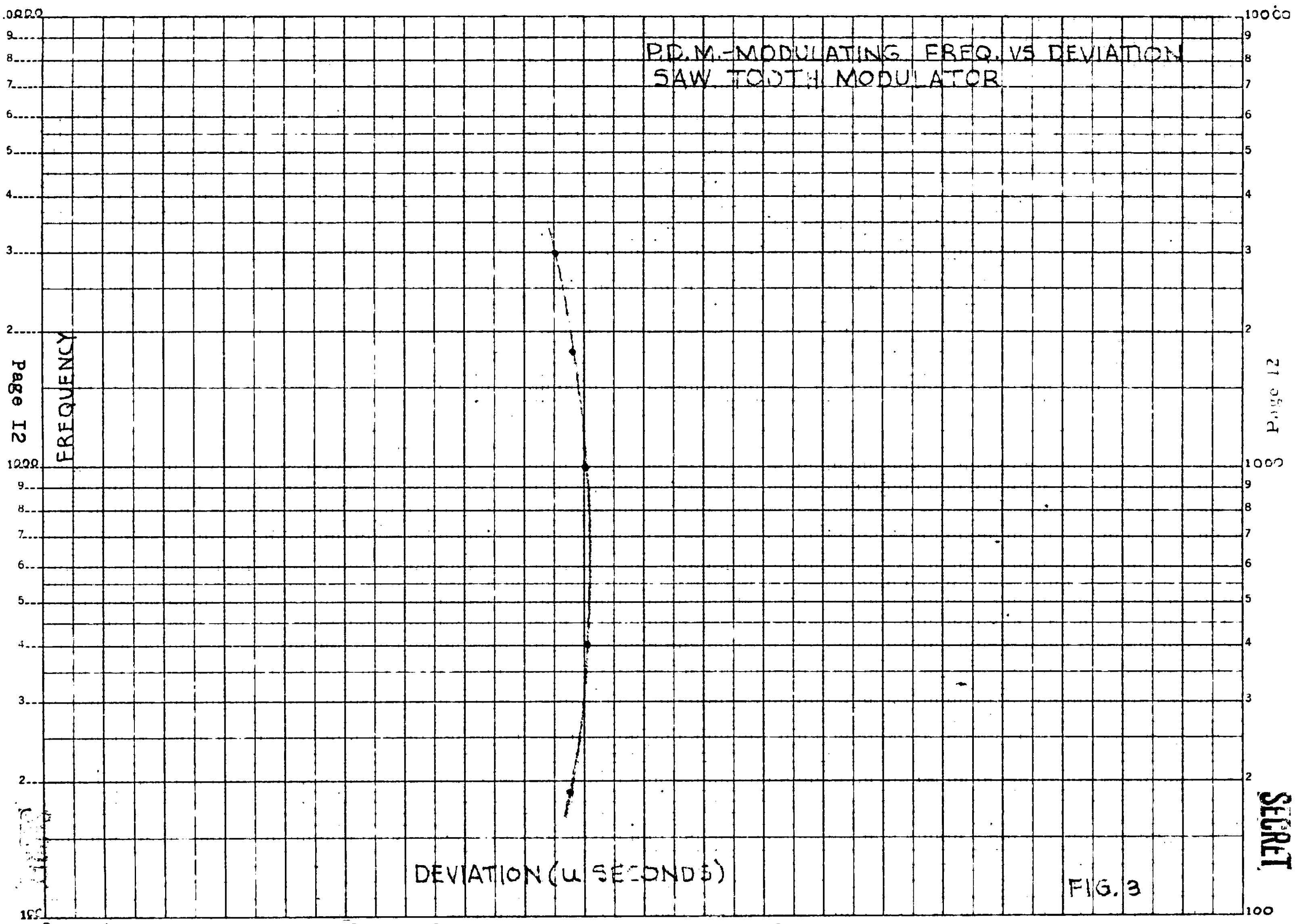
P.D.M.-MODULATING FREQ. VS DEVIATION
SAW TOOTH MODULATOR
FREQUENCY
DEVIATION (u SECONDS)
Page 12

FIG. 3

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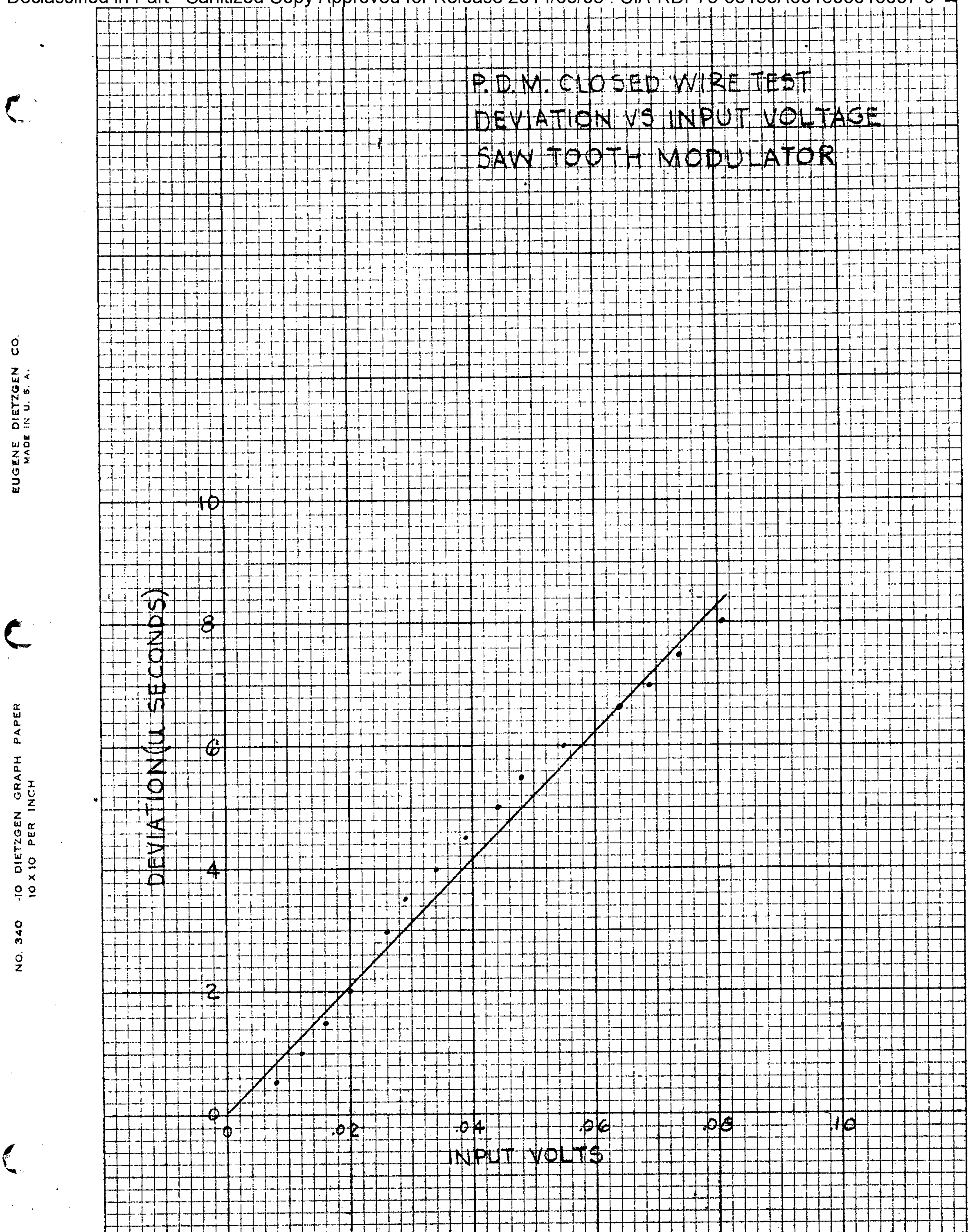
P.D.M. CLOSED WIRE TEST
DEVIATION VS INPUT VOLTAGE
SAW TOOTH MODULATOR
DEVIATION (μ SECONDS)
10
8
6
4
2
0
0
.02
.04
.06
.08
.10
INPUT VOLTS
EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 340 -10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

FIG. 4

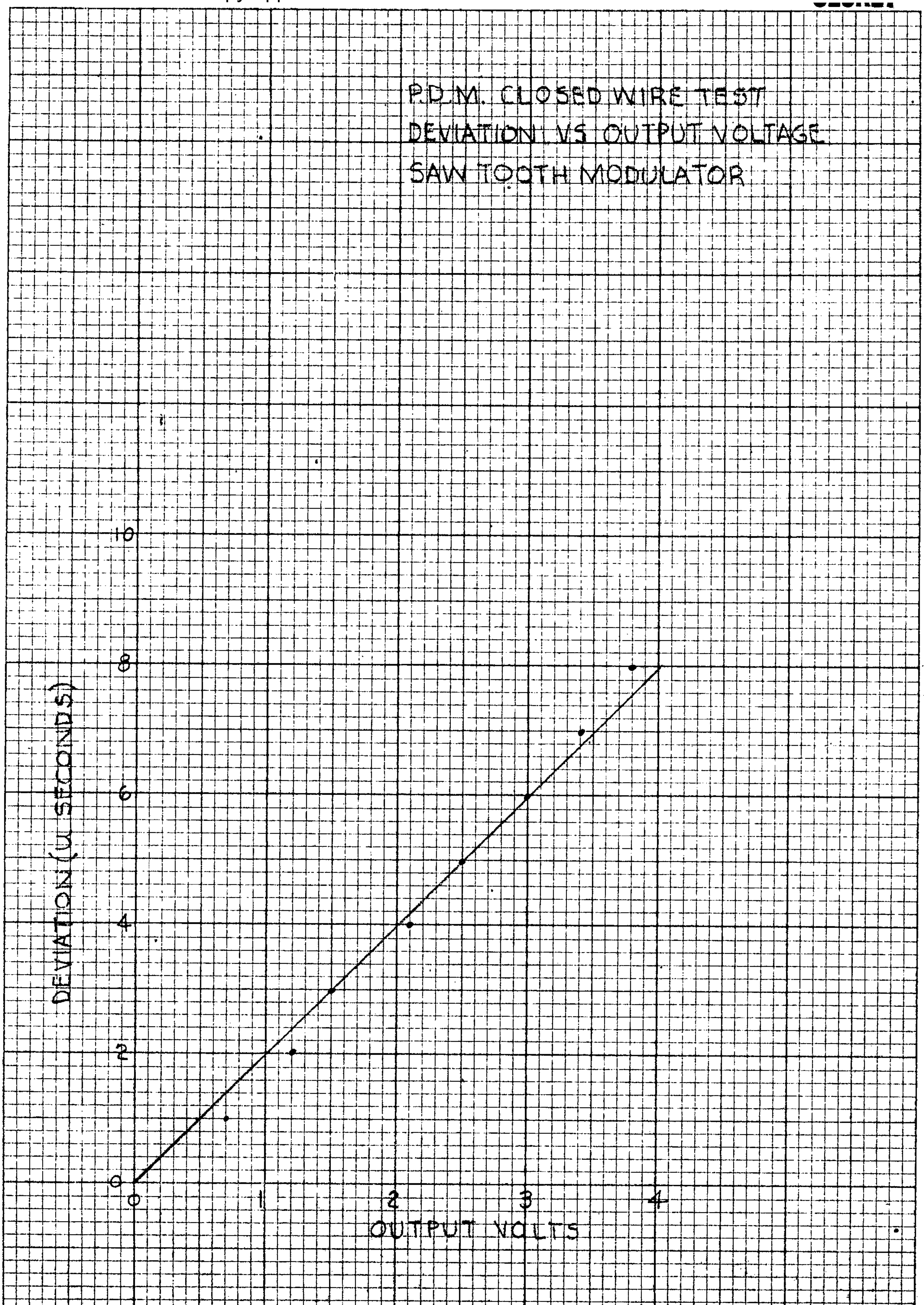
P.D.M. CLOSED WIRE TEST
DEVIATION VS OUTPUT VOLTAGE
SAW TOOTH MODULATOR
DEVIATION (U SECONDS)
OUTPUT VOLTS
0
2
4
6
8
10
0
1
2
3
4

FIG. 5

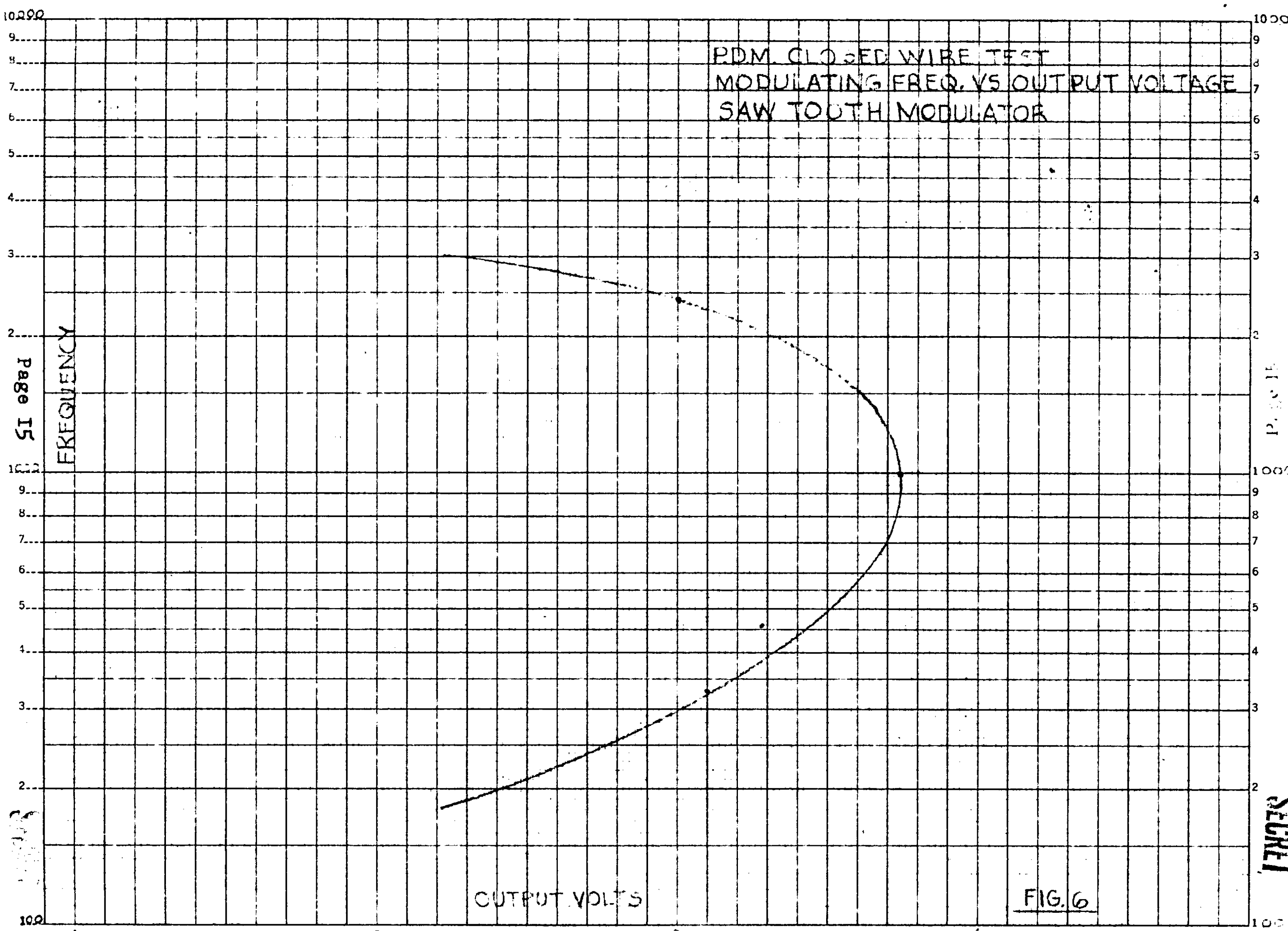
PDM. CLOSED WIRE TEST
MODULATING FREQ. VS OUTPUT VOLTAGE
SAW TOOTH MODULATOR
FREQUENCY
OUTPUT VOLTS
10000
1000
100

FIG. 6

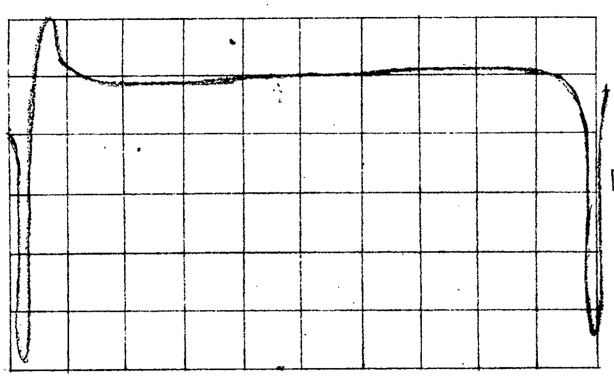

FIG. 7

SENSITIVITY - V/CM 38
SWEEP - μ SEC/CM 13
SIGNAL A

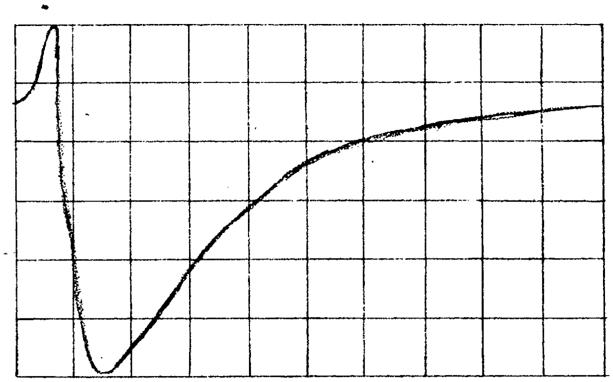

FIG 8

SENSITIVITY - V/CM 5
SWEEP - μ SEC/CM 9.5
SIGNAL B

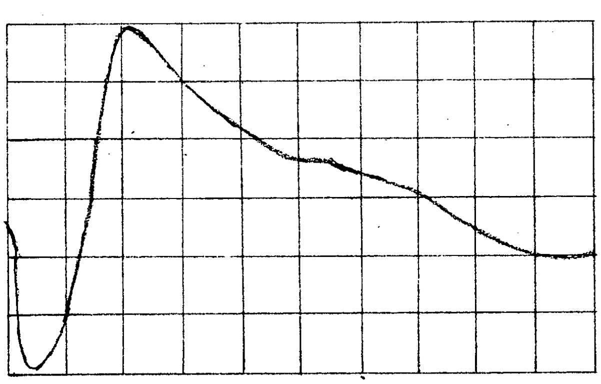

FIG. 9

SENSITIVITY - V/CM 10
SWEEP - μ SEC/CM 2
SIGNAL C

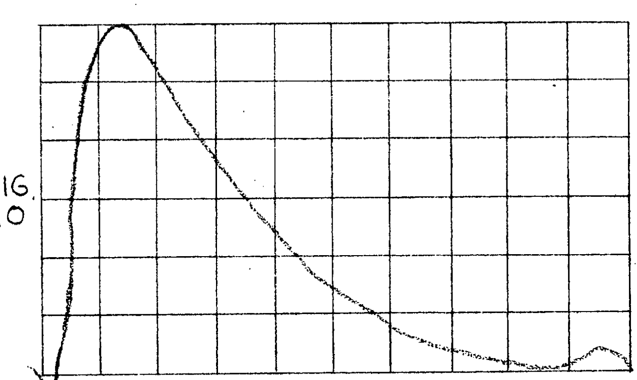

FIG. 10

SENSITIVITY - V/CM 4
SWEEP - μ SEC/CM 1
SIGNAL D

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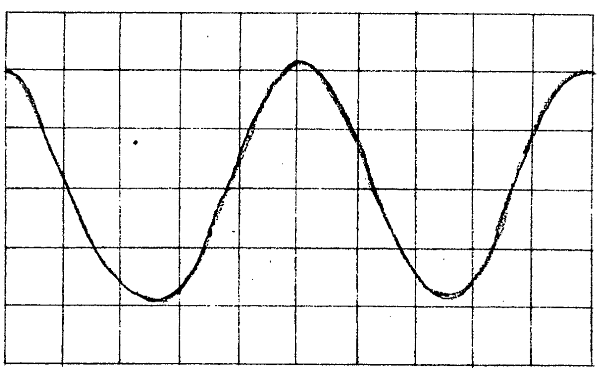

FIG. 11

SENSITIVITY - V/CM .025
SWEEP - μ SEC/CM 200
SIGNAL E

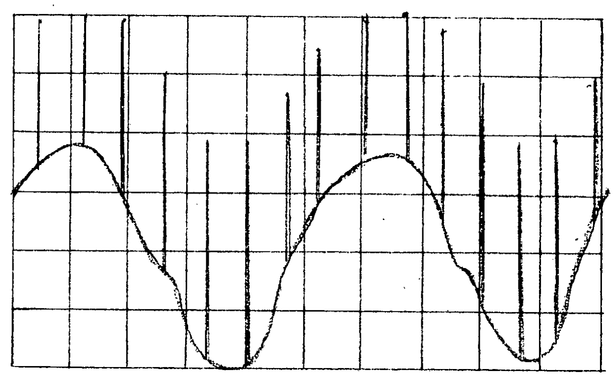

FIG. 12

SENSITIVITY - V/CM 8
SWEEP - μ SEC/CM 200
SIGNAL F

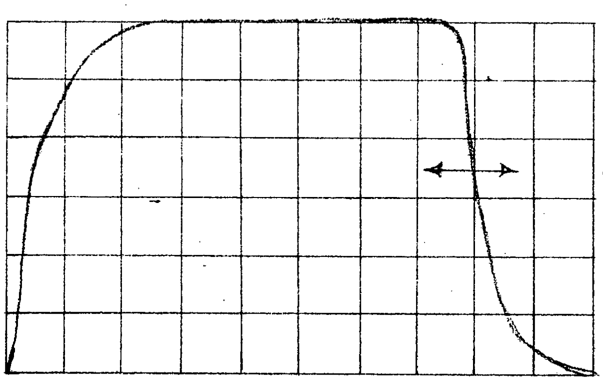

FIG. 13

SENSITIVITY - V/CM 9
SWEEP - μ SEC/CM 1
SIGNAL G

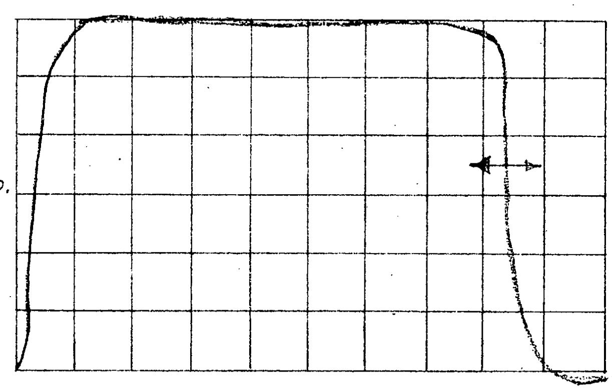

FIG. 14

SENSITIVITY - V/CM .12
SWEEP - μ SEC/CM 1
SIGNAL H

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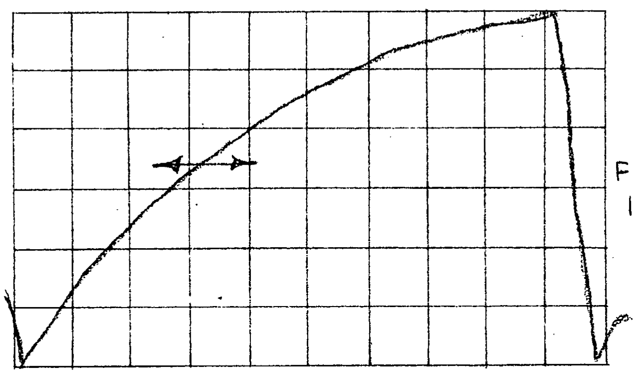

FIG. 15

SENSITIVITY - V/CM 1
SWEEP - μ SEC/CM 13
SIGNAL I

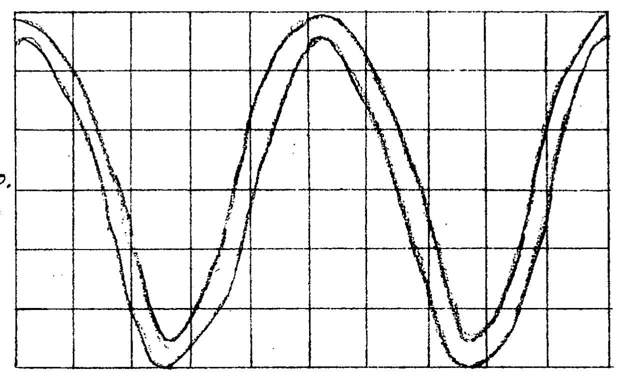

FIG. 16

SENSITIVITY - V/CM .25
SWEEP - μ SEC/CM 200
SIGNAL J

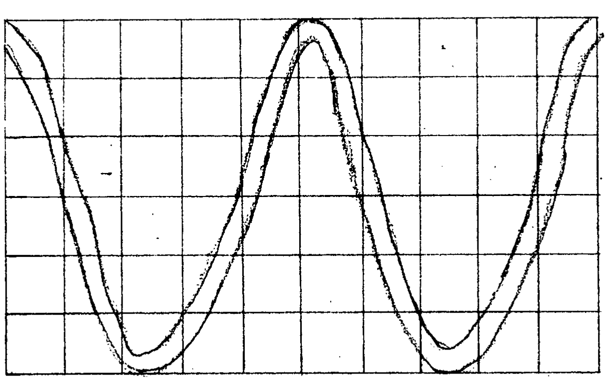

FIG. 17

SENSITIVITY - V/CM 6
SWEEP - μ SEC/CM 200
SIGNAL K

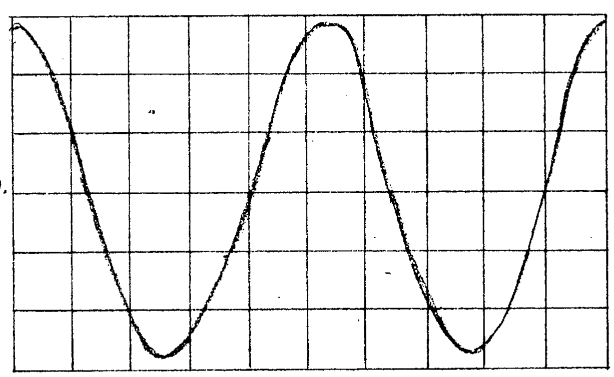

FIG. 18

SENSITIVITY - V/CM 5
SWEEP - μ SEC/CM 200
SIGNAL L

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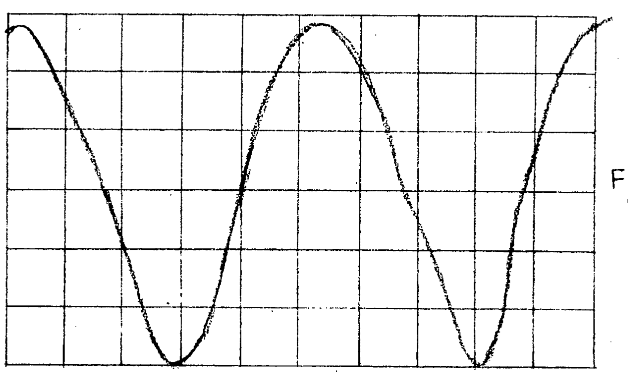

FIG. 19

SENSITIVITY - V/CM 1
SWEEP - μ SEC/CM 200
SIGNAL M

SENSITIVITY - V/CM
SWEEP - μ SEC/CM
SIGNAL

SENSITIVITY - V/CM
SWEEP - μ SEC/CM
SIGNAL

SENSITIVITY - V/CM
SWEEP - μ SEC/CM
SIGNAL

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